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Study and Application of Variable Period Sampling in Strap-down North Seeking System

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Abstract

In order to shorten the north-seeking time on the basis of ensuring the north-seeking precision, according to working principle and project practice of strap-down north-seeking system, a kind of variable period sampling method is designed based on the traditional stationary sampling period. This method sets the different sampling period on a basis of the sampling difference of dynamically tuned gyro in each measurement position. While ensuring the north-seeking precision in every measurement position, reduce the north-seeking time by shortening the sampling period; avoid the conflict of north-seeking time and north-seeking precision in the stationary period sampling. The experiment results show, this method efficaciously enhances the north-seeking efficiency, which is to reduce the north-seeking time from 4.5min to 3.5min on the base of ensuring the north-seeking precision(less than 30″).

Keywords: automatic control technology; dynamically tuned gyro; strap-down north seeking; variable period; sampling

1. Introduction

Multi-position strap-down north-seeking system is a gyro compass north-seeking device, which is developed according to multi-position technology. Gyro compass is a kind of navigational instrument, which can search and track the local geographical meridian plane automatically. Gyro compass, using the comprehensive effect of earth rotation angular velocity and gravitational field, makes the rotation axis of the 2-DOF gyroscope to seek true north automatically. Actually, this true north is the direction, which is determined by north component of the earth rotation angular velocity. It is the equipment that gyro is used as sensitive device to indicate true north, and strong autonomy is the most important feature, so it can provide azimuth reference for inertial navigation system or directional measuring device [1-4]. The main purposes of north-seeking researchers are improving the precision of measurement, shortening the measuring time and simplifying instrument structure.

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In the multi-position strap-down north-seeking system, precision and time are two significant performance and inter-restrictive contradictions. The conflict of north-seeking precision and north-seeking time seriously restricts to the development of rapid high-accuracy multi-position strap-down north seeking system. In the multi-position strap-down north seeking system, dynamically tuned gyro is the important component of the north-seeking system [5], and the measuring data of its single-point output is an important factor that affects the whole north-seeking precision, while the single-point measuring precision depends on the gyro stabilization time. If we can choose gyro stabilization time and sampling time, we will shorten the north- seeking time effectively on the basis of ensuring the measuring precision of single-point gyro.

On the base of studying gyro data-output and gathering principle, in this paper, we study how to shorten the whole north-seeking time by using variable period sampling technology under the condition of ensuring the north-seeking precision.

2. Multi-position Strap-down North-seeking Principle

Install dynamically tuned gyro to the turntable vertically, so the sensing axis is parallel to the table-board and to sense the earth rotary angular velocity. To control the turntable run from initial position, contrarotate, pause, rotate, pause and so on. The turntable pauses in n angular positions in a circle. The data of gyro's output signal and position signal of the turntable is sampled in every position; the process is as shown as figure 1.

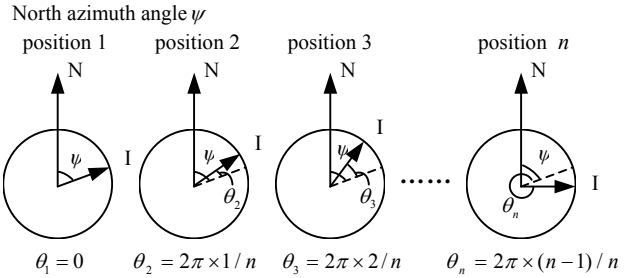

Figure 1. The sketch map of system working flow

In a circle, on the n angular position of the turntable, the math model of gyro output is (1).

$$y_i = R + \omega_N \cos(\theta_i - \psi) + w_i \quad (1)$$

In this equation: y_i is the output of gyro, R is the constant drift of gyro, w_i is the measuring noise of gyro, ω_N is north component of the earth rotation angular velocity, θ_i is the angular position of the turntable.

The mathematical model of gyro output is shown in figure 2. When the gyro output y_i is the maximum, ψ is the true north direction [6].

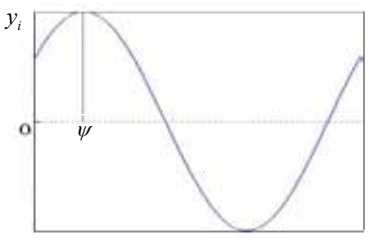

Figure 2. The mathematical model of gyro output

3. Times of Gyro Stabilization and Data Acquisition

On the base of ensuring the position precision, to make the time turntable run to the appointed position as fast as possible. In the experiment, the positioning time is not more than 0.2s, which affects the whole north-seeking time slightly. The emphasis what we study is how to deal with the relation between gyro stabilization time and data acquisition time reasonably, that can shorten the whole north-seeking time of the multi-position strap-down north seeking system effectively.

When the gyro stabilization time is not enough, we will get data with great disturbance. So single-point measuring precision will be debased. According to the situation of servo control, choose gyro stabilization time and initiative point of data acquisition time reasonably, and choose appropriate data acquisition window to ensure single-point gyro output precision, so the sampling time of gyroscope at this position can be saved effectively.

4. Variable Period Sampling Method

4.1 Stationary Period Sampling

For the multi-position strap-down north seeking system, the period of stationary period sampling is an invariant constant. No matter how long dynamically tuned gyro stop and stay at this point, the starting time of sampling fixed. It depends on the choice for time window.

If the numbers of north-seeking position n is 90 and the single-point sampling time T is 3s, then the whole north-seeking time is 4.5min. Timing-sequence relation is shown as figure 3. In this map, T is the sampling period of every measuring position, t1 is the running time of turntable of every specified measuring position, t2 is gyro stabilization time at every measuring position, t3 is gyro signal gathering time, T=t1+t2+t3.

Because turntable running time t1 and gyro stabilization time t2 are different at every measuring position, to ensure gyro sampling precision at every measuring position, we set stationary sampling period: t1=0.25s, t2=2.25s, t3=0.5s. In order to ensure gyro sampling precision at each measuring position, t1, t2 and t3 value are all maximum value basically. Then maybe a lot of invalid waiting time artificially is increased, so the whole north-seeking time is lengthen correspondingly.

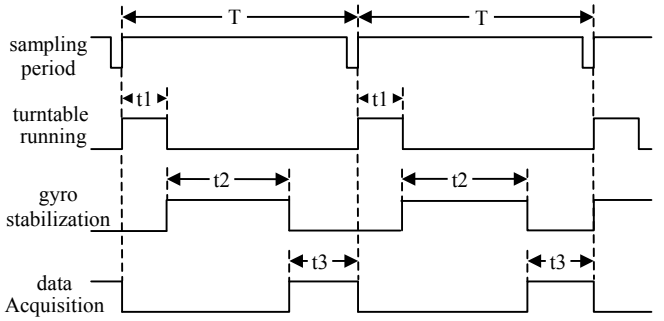

Figure 3. The timing sketch map of north seeking flow

From the experiment, the gyro stabilization time occupies most of north-seeking time. To shorten the gyro stabilization time, then the north-seeking technical performance can be improved further.

4.2 Varlable Period Sampling

The basic difference of variable period sampling and stationary period sampling in time-domain is that the sampling period is variable. In every time window, according to some criterion rule to judge the data, if it meets the requirement， then the starting time of sampling will be advanced. So the sampling times at every sampling-point are different each other. Comparing the data sequence of variable period sampling in time-domain with stationary period sampling in time-domain, the same result can be got by using less

sampling points; in other words, variable period sampling can obtain the same cognizable information by using less sampling points than time-domain stationary period sampling [7-8].

On the base of this theory mentioned, a kind of variable period sampling method is designed, which ensures gyro to own enough stabilization time at every measuring position and avoids wasting a lot of waiting time in measuring process, thus ensuring the north-seeking measuring precision, at the same time, shortening north-seeking time.

Figure 4 is the flow chart of variable period sampling.

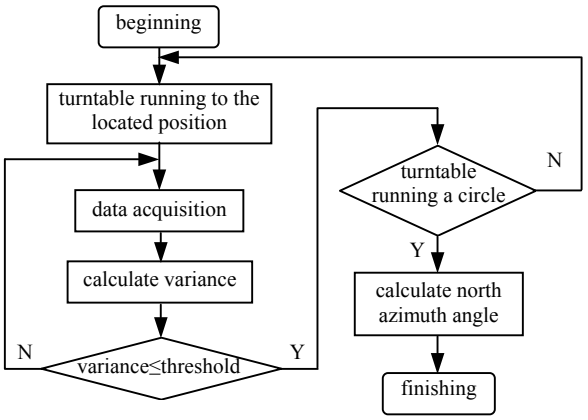

Figure 4. The flow chart of variable period sampling

In the north-seeking process, firstly, servo unit controls the turntable running to the located position. Secondly, processing unit gathers gyro real-time signal circularly and calculate variance. If the variance is less than certain threshold value, then the gyro has been stabilized. So the gyro data gathered from the current position is saved, and these steps are repeated until the turntable runs a circle.

5. Experiment Result

In the experiment, first, we mark the north benchmark prism by astronomical observation method [9]. Second, we use Leica theodolite to measure the measuring errors between north-seeking system and northward-standard. Experiment is taken many times, and one group of data is chosen to make analysis. It is as shown figure 5 and figure 6.

Figure 5 shows the time of turntable running in this experiment. The abscissa denotes the position which represents the pause of turntable, and the ordinate denotes the locating time at each measuring position (unit: second). From the experiment result, the maximum time of locating is 0.19s, the minimum is 0.11s, and most time range is from 0.15s to 0.18s.

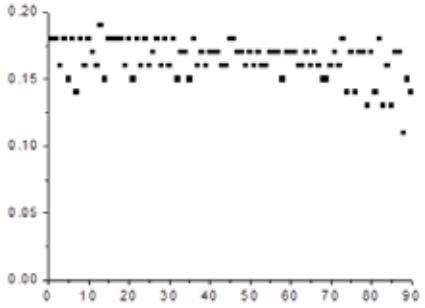

Figure 5. The time of turntable turning

Figure 6 shows the time of gyro stabilizing in this experiment. The abscissa denotes the position which represents the pause of turntable, and the ordinate denotes the time of gyro stabilizing at every measuring position (unit: second). From the figure, we can see that the longest time of gyro stabilizing is 2.2s, and the shortest one is 1.1s, and most time concentrates from 1.5s to 1.9s.

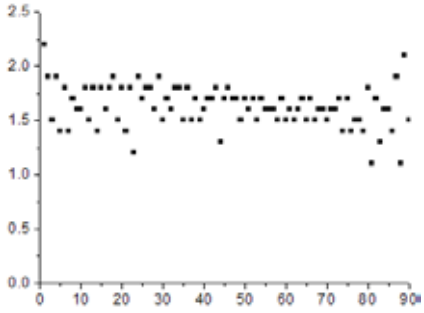

Figure 6. The time of gyro stabilizing

In this experiment, north-seeking system points a stationary direction. When stationary sampling period is used, the north-seeking time is 4.5min, and the north-seeking error is -30″. While variable sampling period is used, the north-seeking error is -46″, and the north-seeking time is only 3.43min.

The stationary period sampling and variable period sampling is adopted respectively by setting 12 different direction-points randomly in this experiment. North-seeking time and north-seeking error are shown as Table 1.

TABLE I. Measuring Data

serial number	stationary sampling period		variable sampling period	
	error (″)	time (min)	error (″)	time (min)
1	-30	4.50	-46	3.43
2	-21	4.50	-16	3.41
3	-16	4.50	-8	3.36
4	37	4.50	25	3.39
5	25	4.50	28	3.40
6	-19	4.50	-27	3.35
7	37	4.50	23	3.45
8	-21	4.50	-26	3.43
9	-37	4.50	-29	3.41
10	8	4.50	2	3.40
11	4	4.50	-5	3.39
12	30	4.50	41	3.38

The 12 groups of measuring data in table 1 are used to calculate the north-seeking precision at stationary period and variable period. Bacause the measuring error is elongs to normal distribution basically, so the standard deviation is used to calculate the north-seeking precision.

When stationary sampling period is used, the north-seeking time is 4.5min, and the north-seeking precision is 27.15″. While variable sampling period is adopted, the north-seeking time is not more than 3.5min, and the north-seeking precision is 27.52″. It is so clear that under the condition of ensuring the north-seeking precision, variable period sampling method can shorten north-seeking time effectively.

6. Conclusions

On the basis of introducing the working principle of multi-position strap-down north-seeking system, this paper has particularly analyzed the impact of data sampling time selection and data processing speed

on gyro single-point north-seeking time in multi-position strap-down north-seeking system. According to the actual conditions of traditional stationary period sampling and the problem of the single point north-seeking data gathering, variable period sampling method is put forward according to measuring value variance in the paper. This method deals with the relationship between gyro stabilization time and data acquisition time reasonably. It can not only ensure gyro stabilization time at every measuring position, but also avoid wasting too much waiting time at this position, thereby improve the efficiency of north-seeking system. The experiment results show that this method efficaciously reduces the north-seeking time from 4.5min to 3.5min on the base of ensuring the north-seeking measuring precision, and it is an effective way to ensure north-seeking precision to realize north seeking quickly.

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